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OF

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FOR

SERINE PROTEASE POLYPEPTIDES AND MATERIALS AND METHODS FOR MAKING THEM

PATENT
97-16

Description

SERINE PROTEASE POLYPEPTIDES AND MATERIALS AND METHODS FOR MAKING THEM

BACKGROUND OF THE INVENTION

Enzymes are used within a wide range of applications in industry, research, and medicine. Through the use of enzymes, industrial processes can be carried out at reduced temperatures and pressures and with less dependence on the use of corrosive or toxic substances. The use of enzymes can thus reduce production costs, energy consumption, and pollution as compared to non-enzymatic products and processes.

An important group of enzymes is the proteases, which cleave proteins. Industrial applications of proteases include food processing, brewing, and alcohol production. Proteases are important components of laundry detergents and other products. Within biological research, proteases are used in purification processes to degrade unwanted proteins. It is often desirable to employ proteases of low specificity or mixtures of more specific proteases to obtain the necessary degree of degradation.

Proteases are also key components of a broad range of biological pathways, including blood coagulation and digestion. For example, the absence or insufficiency of a protease can result in a pathological condition that can be treated by replacement or augmentation therapy. Such therapies include the treatment of hemophilia with clotting factors VIII, IX, and VIIa. In another application, the proteolytic enzyme tissue plasminogen activator (t-PA) is used to activate the body's clot lysing mechanism, thereby reducing morbitity resulting from myocardial infarction. The protease thrombin is used

to initiate the clotting of fibrinogen-based tissue adhesives during surgery. Neutrophils produce several antibacterial serine proteases (Gabay, Ciba Found. Symp. 186:237-247, 1994; Scocchi et al., Eur. J. Biochem. 209:589-595, 1992). Proteases also regulate cellular processes through receptor-mediated pathways by proteolytic activation of the cognate receptor (Vu et al., Cell 64:1057-1068, 1991; Blackhart et al., J. Biol. Chem. 271:16466-16471, 1996).

Overproduction or lack of regulation of proteases can also have pathological consequences. Elastase, released within the lung in response to the presence of foreign particles, can damage lung tissue if its activity is not tightly regulated. Emphysema in smokers is believed to arise from an imbalance between elastase and its inhibitor, alpha-1-antitrypsin. This balance may be restored by administration of exogenous alpha-1-antitrypsin.

One family of proteases of particular interest is the serine proteases, which are characterized by a catalytic triad of serine, histidine, and aspartic acid residues. Serine proteases are used for a variety of industrial purposes. For example, the serine protease subtilisin is used in laundry detergents to aid in the removal of proteinaceous stains (e.g., Crabb, ACS Symposium Series 460:82-94, 1991). In the food processing industry, serine proteases are used to produce protein-rich concentrates from fish and livestock, and in the preparation of dairy products (Kida et al., Journal of Fermentation and Bioengineering 80:478-484, 1995; Haard and Simpson, in Martin, A.M., ed., Fisheries Processing: Biotechnological Applications, Chapman and Hall, London, 1994, 132-154; Bos et al., European Patent Office Publication 494 149 A1).

In general, enzymes, including proteases, are active over a narrow range of environmental conditions

(temperature, pH, etc.), and many are highly specific for particular substrates. The narrow range of activity for a given enzyme limits its applicability and creates a need for a selection of enzymes that (a) have similar activities but are active under different conditions or (b) have different substrates. For instance, an enzyme capable of catalyzing a reaction at 50°C may be so inefficient at 35°C that its use at the lower temperature will not be feasible. For this reason, laundry detergents generally contain a selection of proteolytic enzymes, allowing the detergent to be used over a broad range of wash temperature and pH.

In view of the specificity of proteolytic enzymes and the growing use of proteases in industry, research, and medicine, there is an ongoing need in the art for new enzymes and new enzyme inhibitors. The present invention addresses these needs and provides other, related advantages.

SUMMARY OF THE INVENTION

Within one aspect, the present invention provides an isolated protein comprising a sequence of amino acid residues that is at least 95% identical to SEQ ID NO:2 from Ile, residue 111, through Asn, residue 373, wherein the protein is a protease or protease precursor. In one embodiment, the protein has from 263 to 398 amino acid residues. In other embodiments, the protein comprises residues 111 through 373 of SEQ ID NO:2 or SEQ ID NO:15, residues 110 through 373 of SEQ ID NO:2 or SEQ ID NO:15, or residues 1 through 373 of SEQ ID NO:2 or SEQ ID NO:15. The protein can further comprise a heterologous affinity tag or binding domain.

Within a second aspect, the invention provides an isolated polynucleotide up to 1800 nucleotides in length encoding a protein as disclosed above. Within one embodiment, the polynucleotide is DNA. Within another

embodiment, the polynucleotide is double-stranded DNA. Within a further embodiment, the protein encoded by the polynucleotide comprises residues -19 through 373 of SEQ ID NO:2.

Within a third aspect, the invention provides an expression vector comprising the following operably linked elements: (a) a transcription promoter; (b) a DNA segment encoding a protein as disclosed above; and (c) a transcription terminator. The expression vector can further comprise a secretory signal sequence operably linked to the DNA segment.

The invention also provides a cultured cell containing an expression vector as disclosed above, wherein the cell expresses the DNA segment. Within one embodiment of the invention the expression vector further comprises a secretory signal sequence operably linked to the DNA segment, and the cell secretes the protein.

There is also provided a method of making a protease or protease precursor. The method comprises the steps of (a) providing a host cell containing an expression vector as disclosed above; (b) culturing the host cell under conditions whereby the DNA segment is expressed; and (c) recovering the protein encoded by the DNA segment. Within one embodiment the expression vector further comprises a secretory signal sequence operably linked to the DNA segment, the cell secretes the protein into a culture medium, and the protein is recovered from the medium.

Within a further aspect of the invention there is provided a method of cleaving a peptide bond of a substrate protein. The method comprises incubating the substrate protein in the presence of a second protein comprising a sequence of amino acid residues that is at least 95% identical to SEQ ID NO:2 from Ile, residue 111, through Asn, residue 373, whereby the peptide bond is cleaved. Within one embodiment, the second protein is a

protease precursor and the method further comprises the step of activating the second protein before the peptide bond is cleaved.

The invention further provides a method of detecting an inhibitor of proteolysis within a test sample comprising the steps of (a) measuring proteolytic activity of a protein as disclosed above in the presence of a test sample to obtain a first value; (b) measuring proteolytic activity of the protein in the absence of the test sample to obtain a second value; and (c) comparing the first and second values, whereby a higher second value relative to the first value is indicative of an inhibitor of proteolysis within the test sample.

The invention also provides an antibody that specifically binds to a protein comprising a sequence of amino acid residues that is at least 95% identical to SEQ ID NO:2 from Ile, residue 111, through Asn, residue 373, wherein the protein is a protease or protease precursor.

Within an additional aspect, the invention provides a DNA construct encoding a polypeptide fusion. The polypeptide fusion comprises, from amino terminus to carboxyl terminus, amino acid residues -19 through -1 of SEQ ID NO:2 operably linked to an additional polypeptide.

These and other aspects of the invention will become evident upon reference to the following detailed description of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Prior to setting forth the invention in detail, certain terms used herein will be defined.

The term "allelic variant" denotes any of two or more alternative forms of a gene occupying the same chromosomal locus. Allelic variation arises naturally through mutation, and may result in phenotypic polymorphism within populations. Gene mutations can be silent (no change in the encoded polypeptide) or may

encode polypeptides having altered amino acid sequence. The term "allelic variant" is also used herein to denote a protein encoded by an allelic variant of a gene.

The term "complements of polynucleotide molecules" denotes polynucleotide molecules having a complementary base sequence and reverse orientation as compared to a reference sequence. For example, the sequence 5' ATGCACGGG 3' is complementary to 5' CCCGTGCAT 3'.

The term "degenerate nucleotide sequence" denotes a sequence of nucleotides that includes one or more degenerate codons (as compared to a reference polynucleotide molecule that encodes a polypeptide). Degenerate codons contain different triplets of nucleotides, but encode the same amino acid residue (i.e., GAU and GAC triplets each encode Asp).

A "DNA construct" is a single or double stranded, linear or circular DNA molecule that comprises segments of DNA combined and juxtaposed in a manner not found in nature. DNA constructs exist as a result of human manipulation, and include clones and other copies of manipulated molecules.

A "DNA segment" is a portion of a larger DNA molecule having specified attributes. For example, a DNA segment encoding a specified polypeptide is a portion of a longer DNA molecule, such as a plasmid or plasmid fragment, that, when read from the 5' to the 3' direction, encodes the sequence of amino acids of the specified polypeptide.

The term "expression vector" denotes a DNA construct that comprises a segment encoding a polypeptide of interest operably linked to additional segments that provide for its transcription in a host cell. Such additional segments may include promoter and terminator sequences, and may optionally include one or more origins of replication, one or more selectable markers, an

enhancer, a polyadenylation signal, and the like. Expression vectors are generally derived from plasmid or viral DNA, or may contain elements of both.

The term "isolated", when applied to a polynucleotide molecule, denotes that the polynucleotide has been removed from its natural genetic milieu and is thus free of other extraneous or unwanted coding sequences, and is in a form suitable for use within genetically engineered protein production systems. Such isolated molecules are those that are separated from their natural environment and include cDNA and genomic clones, as well as synthetic polynucleotides. Isolated DNA molecules of the present invention may include naturally occurring 5' and 3' untranslated regions such as promoters and terminators. The identification of associated regions will be evident to one of ordinary skill in the art (see for example, Dynan and Tijan, Nature 316:774-78, 1985). When applied to a protein, the term "isolated" indicates that the protein is found in a condition other than its native environment, such as apart from blood and animal tissue. In a preferred form, the isolated protein is substantially free of other proteins, particularly other proteins of animal origin. It is preferred to provide the protein in a highly purified form, i.e., at least 90% pure, preferably greater than 95% pure, more preferably greater than 99% pure.

The term "operably linked", when referring to DNA segments, denotes that the segments are arranged so that they function in concert for their intended purposes, e.g. transcription initiates in the promoter and proceeds through the coding segment to the terminator.

The term "ortholog" denotes a polypeptide or protein obtained from one species that is the functional counterpart of a polypeptide or protein from a different species. Sequence differences among orthologs are the result of speciation.

The term "polynucleotide" denotes a single- or double-stranded polymer of deoxyribonucleotide or ribonucleotide bases read from the 5' to the 3' end. Polynucleotides include RNA and DNA, and may be isolated from natural sources, synthesized *in vitro*, or prepared from a combination of natural and synthetic molecules. The length of a polynucleotide molecule is given herein in terms of nucleotides (abbreviated "nt") or base pairs (abbreviated "bp"). The term "nucleotides" is used for both single- and double-stranded molecules where the context permits. When the term is applied to double-stranded molecules it is used to denote overall length and will be understood to be equivalent to the term "base pairs". It will be recognized by those skilled in the art that the two strands of a double-stranded polynucleotide may differ slightly in length and that the ends thereof may be staggered as a result of enzymatic cleavage; thus all nucleotides within a double-stranded polynucleotide molecule may not be paired. Such unpaired ends will in general not exceed 20 nt in length.

The term "promoter" denotes a portion of a gene containing DNA sequences that provide for the binding of RNA polymerase and initiation of transcription. Promoter sequences are commonly, but not always, found in the 5' non-coding regions of genes.

A "protease" is an enzyme that cleaves peptide bonds in proteins. A "protease precursor" is a relatively inactive form of the enzyme that commonly becomes activated upon cleavage by another protease.

The term "secretory signal sequence" denotes a DNA sequence that encodes a polypeptide (a "secretory peptide") that, as a component of a larger polypeptide, directs the larger polypeptide through a secretory pathway of a cell in which it is synthesized. The larger polypeptide is commonly cleaved to remove the secretory peptide during transit through the secretory pathway.

All references cited herein are incorporated by reference in their entirety.

The present invention provides novel serine proteases, serine protease precursors, and useful polypeptide fragments thereof. The sequence of a representative protein of the present invention is shown in SEQ ID NO:2. This protein shows significant amino acid sequence homology to several serine proteases, including *Bacillus licheniformis* glutamyl endopeptidase (Svendsen and Breddam, Eur. J. Biochem. 204:165-171, 1992), human clotting factor X (Leytus et al., Biochem. 25:5098-5102, 1986), human elastase (Kawashima et al., DNA 6:163-172, 1987), rat mast cell protease (Benfey et al., J. Biol. Chem. 262:5377-5384, 1987), *Streptomyces griseus* trypsin (Kim et al., Biochem. Biophys. Res. Comm. 181:707-713, 1991), *Hypoderma lineatum* collagenase (J. Biol. Chem. 262:7546-7551, 1987), and bovine trypsinogen (Titani et al., Biochem. 14:1358-1366, 1975). The protein has been designated "Zsig13".

A Zsig13 polynucleotide sequence was initially identified by querying a database of expressed sequence tags (ESTs) for secretory signal sequences characterized by an upstream methionine start site, a hydrophobic region of approximately 13 amino acid residues, and a cleavage site as defined by von Heijne (Nuc. Acids Res. 14:4683, 1986). Analysis of a full-length DNA (shown in SEQ ID NO:1) revealed its homology with other members of the serine protease family. Northern blot analysis indicated the presence of two corresponding messages, a predominant transcript of approximately 1.8 kb and a secondary transcript of approximately 4 kb. The sequence of SEQ ID NO:1 consists of 1634 bp, not including a poly(A) tail. The sequence includes an open reading frame of 1176 base pairs.

An alignment of Zsig13 with related proteins was used to identify the catalytic triad of His (156), Asp

(227) and Ser (322) as shown in SEQ ID NO:2. The Leu-Thr-Ala-Ala-His-Cys sequence (residues 152-157 of SEQ ID NO:2) is a characteristic active site His signature within serine proteases. Resides -1 through -19 of SEQ ID NO:2 make up a putative signal peptide. Residues 106-109 of SEQ ID NO:2 (Arg-Arg-Lys-Arg) are a characteristic cleavage site; such cleavage may serve a regulatory function, such as activation of the protein during or after secretion. Activation by proteolytic cleavage is common among serine proteases. While not wishing to be bound by theory, the protein is believed to become active following exposure of a free amino group on Gln 110 or, with additional processing, Ile 111. However, in contrast to many other serine proteases, the non-catalytic, amino-terminal fragment does not appear to remain tethered to the remainder of the molecule after this cleavage has occurred. Alignment of sequences further indicates that active site contact residues are at positions 244 (Ile), 291 (Asp), 292 (Ala), 316 (Lys), 317 (Ile), 328 (Asp), 350 (Ile), 356 (Gly), 358 (Tyr) and 360 (Asp) of SEQ ID NO:2. Sequence alignment identified the Lys residue at position 316 as the key residue in the base of the P1 ligand specificity pocket, generating specificity for Glu and/or Asp in the P1 position of the substrate protein.

With reference to SEQ ID NO:2, additional structural features of Zsig13 include paired cysteine residues at positions 46 and 50, 141 and 157, 276 and 290, and 351 and 361. Potential N-linked glycosylation sites are at residues Asn-74 and Asn-188. The calculated molecular weight of the peptide backbone of the 392-residue precursor is 43,829.55, with a predicted pI of 10.44. The calculated peptide backbone molecular weight of residues 110-373 is 30,074, with a predicted pI of 10.4.

The Zsig13 protein was found to be highly expressed in tissues that are exposed to the external

environment, including trachea, bladder, small intestine, colon, and prostate. This tissue distribution suggests a digestive or anti-bacterial function. Several anti-bacterial serine proteases are known to be produced in neutrophils, where they are stored in granules as inactive proforms (Gabay, ibid.; Scocchi et al., ibid.). Expression was also detected in aorta and fetal kidney.

The present invention also provides isolated Zsig13 polypeptides that are substantially homologous to the polypeptides of SEQ ID NO:2 and their orthologs. The term "substantially homologous" is used herein to denote polypeptides having 50%, preferably 60%, more preferably at least 80%, sequence identity to polypeptides sequences of SEQ ID NO:2 or their orthologs. Such polypeptides will more preferably be at least 90% identical, and most preferably 95% or more identical to polypeptides of SEQ ID NO:2 or their orthologs. Percent sequence identity is determined by conventional methods. See, for example, Altschul et al., Bull. Math. Bio. 48: 603-616, 1986 and Henikoff and Henikoff, Proc. Natl. Acad. Sci. USA 89:10915-10919, 1992. Briefly, two amino acid sequences are aligned to optimize the alignment scores using a gap opening penalty of 10, a gap extension penalty of 1, and the "blosum 62" scoring matrix of Henikoff and Henikoff (ibid.) as shown in Table 1 (amino acids are indicated by the standard one-letter codes). The percent identity is then calculated as:

$$\frac{\text{Total number of identical matches}}{\left[\begin{array}{l}\text{length of the longer sequence plus the number of gaps introduced into the longer sequence in order to align the two sequences}\end{array}\right]} \times 100$$

Table 1

	A	R	N	D	C	Q	E	G	H	I	L	K	M	F	P	S	T	W	Y	V
A	4																			
R	-1	5																		
N	-2	0	6																	
D	-2	-2	1	6																
C	0	-3	-3	-3	9															
Q	-1	1	0	0	-3	5														
E	-1	0	0	2	-4	2	5													
G	0	-2	0	-1	-3	-2	-2	6												
H	-2	0	1	-1	-3	0	0	-2	8											
I	-1	-3	-3	-3	-1	-3	-3	-4	-3	4										
L	-1	-2	-3	-4	-1	-2	-3	-4	-3	2	4									
K	-1	2	0	-1	-3	1	1	-2	-1	-3	-2	5								
M	-1	-1	-2	-3	-1	0	-2	-3	-2	1	2	-1	5							
F	-2	-3	-3	-3	-2	-3	-3	-3	-1	0	0	-3	0	6						
P	-1	-2	-2	-1	-3	-1	-1	-2	-2	-3	-3	-1	-2	-4	7					
S	1	-1	1	0	-1	0	0	0	-1	-2	-2	0	-1	-2	-1	4				
T	0	-1	0	-1	-1	-1	-1	-2	-2	-1	-1	-1	-1	-2	-1	1	5			
W	-3	-3	-4	-4	-2	-2	-3	-2	-2	-3	-2	-3	-1	1	-4	-3	-2	11		
Y	-2	-2	-2	-3	-2	-1	-2	-3	2	-1	-1	-2	-1	3	-3	-2	-2	2	7	
V	0	-3	-3	-3	-1	-2	-2	-3	-3	3	1	-2	1	-1	-2	-2	0	-3	-1	4

Sequence identity of polynucleotide molecules is determined by similar methods using a ratio as disclosed above.

Substantially homologous proteins and polypeptides are characterized as having one or more amino acid substitutions, deletions or additions. These changes are preferably of a minor nature, that is conservative amino acid substitutions (see Table 2) and other substitutions that do not significantly affect the folding or activity of the protein or polypeptide; small deletions, typically of one to about 30 amino acids; and small amino- or carboxyl-terminal extensions, such as an amino-terminal methionine residue, a small linker peptide of up to about 20-25 residues, or a small extension that facilitates purification (an affinity tag), such as a poly-histidine tract, protein A (Nilsson et al., EMBO J. 4:1075, 1985; Nilsson et al., Methods Enzymol. 198:3, 1991), glutathione S transferase (Smith and Johnson, Gene 67:31, 1988), maltose binding protein (Kellerman and Ferenci, Methods Enzymol. 90:459-463, 1982; Guan et al., Gene 67:21-30, 1987), thioredoxin, ubiquitin, cellulose binding protein, T7 polymerase, or other antigenic epitope or binding domain. See, in general Ford et al., Protein Expression and Purification 2: 95-107, 1991. DNAs encoding affinity tags are available from commercial suppliers (e.g., Pharmacia Biotech, Piscataway, NJ; New England Biolabs, Beverly, MA). Zsig13 proteins comprising linkers, affinity tags, or other extensions will typically be from 283 to 398 residues in length, given a polypeptide having an amino terminus within residues 1-111 of SEQ ID NO:2 and a carboxyl terminus at residue 373 of SEQ ID NO:2, and further comprising an extension of 20-25 residues. Those skilled in the art will recognize that polypeptides comprising longer extensions are also within the scope of the present invention.

Table 2

Conservative amino acid substitutions

Basic:	arginine
	lysine
	histidine
Acidic:	glutamic acid
	aspartic acid
Polar:	glutamine
	asparagine
Hydrophobic:	leucine
	isoleucine
	valine
Aromatic:	phenylalanine
	tryptophan
	tyrosine
Small:	glycine
	alanine
	serine
	threonine
	methionine

The proteins of the present invention can also comprise non-naturally occuring amino acid residues. Non-naturally occuring amino acids include, without limitation, *trans*-3-methylproline, 2,4-methanoproline, *cis*-4-hydroxyproline, *trans*-4-hydroxyproline, *N*-methylglycine, *allo*-threonine, methylthreonine, hydroxyethylcysteine, hydroxyethylhomocysteine, nitroglutamine, homoglutamine, pipecolic acid, *tert*-leucine, norvaline, 2-azaphenylalanine, 3-azaphenylalanine, 4-azaphenylalanine, and 4-fluorophenylalanine. Several methods are known in the art for incorporating non-naturally occuring amino acid residues into proteins. For example, an *in vitro* system can be employed wherein nonsense mutations are suppressed using chemically aminoacylated suppressor tRNAs. Methods

for synthesizing amino acids and aminoacylating tRNA are known in the art. Transcription and translation of plasmids containing nonsense mutations is carried out in a cell free system comprising an *E. coli* S30 extract and commercially available enzymes and other reagents. Proteins are purified by chromatography. See, for example, Robertson et al., J. Am. Chem. Soc. 113:2722, 1991; Ellman et al., Methods Enzymol. 202:301, 1991; Chung et al., Science 259:806-809, 1993; and Chung et al., Proc. Natl. Acad. Sci. USA 90:10145-10149, 1993). In a second method, translation is carried out in Xenopus oocytes by microinjection of mutated mRNA and chemically aminoacylated suppressor tRNAs (Turcatti et al., J. Biol. Chem. 271:19991-19998, 1996). Within a third method, *E. coli* cells are cultured in the absence of a natural amino acid that is to be replaced (e.g., phenylalanine) and in the presence of the desired non-naturally occuring amino acid(s) (e.g., 2-azaphenylalanine, 3-azaphenylalanine, 4-azaphenylalanine, or 4-fluorophenylalanine). The non-naturally occuring amino acid is incorporated into the protein in place of its natural counterpart. See, Koide et al., Biochem. 33:7470-7476, 1994. Naturally occuring amino acid residues can be converted to non-naturally occuring species by *in vitro* chemical modification. Chemical modification can be combined with site-directed mutagenesis to further expand the range of substitutions (Wynn and Richards, Protein Sci. 2:395-403, 1993).

Essential amino acids in the Zsig13 polypeptides of the present invention can be identified according to procedures known in the art, such as site-directed mutagenesis or alanine-scanning mutagenesis (Cunningham and Wells, Science 244: 1081-1085, 1989). In the latter technique, single alanine mutations are introduced at every residue in the molecule, and the resultant mutant molecules are tested for biological activity as disclosed above to identify amino acid

residues that are critical to the activity of the molecule. See also, Hilton et al., J. Biol. Chem. 271:4699-4708, 1996. Residues important for substrate binding and cleavage can also be determined by physical analysis of structure, as determined by such techniques as nuclear magnetic resonance, crystallography, electron diffraction or photoaffinity labeling, in conjunction with mutation of putative contact site amino acids. See, for example, de Vos et al., Science 255:306-312, 1992; Smith et al., J. Mol. Biol. 224:899-904, 1992; Wlodaver et al., FEBS Lett. 309:59-64, 1992. The identities of essential amino acids can also be inferred from analysis of homologies with related serine proteases.

Multiple amino acid substitutions can be made and tested using known methods of mutagenesis and screening, such as those disclosed by Reidhaar-Olson and Sauer (Science 241:53-57, 1988) or Bowie and Sauer (Proc. Natl. Acad. Sci. USA 86:2152-2156, 1989). Briefly, these authors disclose methods for simultaneously randomizing two or more positions in a polypeptide, selecting for functional polypeptide, and then sequencing the mutagenized polypeptides to determine the spectrum of allowable substitutions at each position. Other methods that can be used include phage display (e.g., Lowman et al., Biochem. 30:10832-10837, 1991; Ladner et al., U.S. Patent No. 5,223,409; Huse, WIPO Publication WO 92/06204) and region-directed mutagenesis (Derbyshire et al., Gene 46:145, 1986; Ner et al., DNA 7:127, 1988).

Mutagenesis methods as disclosed above can be combined with high-throughput, automated screening methods to detect activity of cloned, mutagenized polypeptides in host cells. Mutagenized DNA molecules that encode proteolytically active proteins or precursors thereof can be recovered from the host cells and rapidly sequenced using modern equipment. These methods allow the rapid determination of the importance of individual

amino acid residues in a polypeptide of interest, and can be applied to polypeptides of unknown structure.

Using the methods disclosed above, one of ordinary skill in the art can identify and/or prepare a variety of polypeptides that are substantially homologous to residues 111 through 373 of SEQ ID NO:2 or allelic variants thereof and retain the proteolytic properties of the wild-type protein. Such polypeptides may include a targetting moiety comprising additional amino acid residues that form an independently folding binding domain. Such domains include, for example, an extracellular ligand-binding domain (e.g., one or more fibronectin type III domains) of a cytokine receptor; immunoglobulin domains; DNA binding domains (see, e.g., He et al., Nature 378:92-96, 1995); affinity tags; and the like. Such polypeptides may also include additional polypeptide segments as generally disclosed above.

In addition to the fusion proteins disclosed above, the present invention provides fusions comprising the secretory peptide of Zsig13 (residues -19 through -1 of SEQ ID NO:2). This secretory peptide can be used to direct the secretion of other proteins of interest by joining a polynucleotide sequence encoding it to the 5' end of a sequence encoding a protein of interest.

Within the present invention, proteins, including variants and fragments of SEQ ID NO:2, can be tested for serine protease activity using conventional assays. Briefly, substrate cleavage is conveniently assayed using a tetrapeptide that mimics the cleavage site of the natural substrate and which is linked, via a peptide bond, to a carboxyl-terminal para-nitro-anilide (pNA) group. The protease hydrolyzes the bond between the fourth amino acid residue and the pNA group, causing the pNA group to undergo a dramatic increase in absorbance at 405 nm. Such substrates will preferably contain a Glu or Asp residue at the P1 position.

Suitable substrates can be synthesized according to known methods or obtained from commercial suppliers. When the serine protease is prepared as an inactive precursor (e.g., comprising N-terminal residues 1-109 of SEQ ID NO:2), it is activated by cleavage with a suitable protease (e.g., furin (Steiner et al., J. Biol. Chem. 267:23435-23438, 1992)) prior to assay. Assays of this type are well known in the art. See, for example, Lottenberg et al., Thrombosis Research 28:313-332, 1982; Cho et al., Biochem. 23:644-650, 1984; Foster et al., Biochem. 26:7003-7011, 1987).

The isolated polynucleotides of the present invention include DNA and RNA. Methods for isolating DNA and RNA are well known in the art. For example, RNA can be isolated from trachea, bladder, small intestine, colon, or prostate, which RNA is then used as a template for preparation of complementary DNA (cDNA). DNA can also be prepared using RNA from other tissues or isolated as genomic DNA. Total RNA can be prepared using guanidine HCl extraction followed by isolation by centrifugation in a CsCl gradient (Chirgwin et al., Biochemistry 18:52-94, 1979). Poly $(A)^+$ RNA is prepared from total RNA using the method of Aviv and Leder (Proc. Natl. Acad. Sci. USA 69:1408-1412, 1972). Complementary DNA (cDNA) is prepared from poly$(A)^+$ RNA using known methods. Polynucleotides encoding Zsig13 polypeptides are then identified and isolated by, for example, hybridization or polymerase chain reaction (PCR).

Within SEQ ID NO:1 and SEQ ID NO:2, residues 80, 95, 96, and 149 can be any amino acid residue (denoted as Xaa). Within a preferred embodiment of the invention, residue 80 is Thr, residue 95 is Gln, residue 96 is His, and residue 149 is Lys.

A second Zsig13 DNA sequence is shown in SEQ ID NO:14 (with the corresponding amino acid sequence shown in SEQ ID NO:15). Within SEQ ID NO:15, residue 60 is

Glu, residue 80 is Thr, residue 95 is Gln, residue 96 is His, residue 149 is Lys, residue 299 is Ser, and residue 369 is Pro. All other residues in SEQ ID NO:15 are the same as their respective counterparts in SEQ ID NO:2. The calculated molecular weight of the peptide backbone of the 392-residue polypeptide shown in SEQ ID NO:15 is 43,918.56, with a predicted pI of 10.38. The calculated peptide backbone molecular weight of residues 110-373 is 28,113.80, with a predicted pI of 10.49.

Those skilled in the art will recognize that the sequences disclosed in SEQ ID NO:14 and SEQ ID NO:15 represent a single allele of the human Zsig13 gene and polypeptide, and that allelic variation and alternative splicing are expected to occur. Allelic variants can be cloned by probing cDNA or genomic libraries from different individuals according to standard procedures. Allelic variants of the DNA sequence shown in SEQ ID NO: 14, including those containing silent mutations and those in which mutations result in amino acid sequence changes, are within the scope of the present invention, as are proteins which are allelic variants of SEQ ID NO:15.

The invention also encompasses degenerate polynucleotide sequences encoding proteins as disclosed above. Those skilled in the art will readily recognize that, in view of the degeneracy of the genetic code, considerable sequence variation is possible among these polynucleotide molecules. SEQ ID NO:16 is a degenerate DNA sequence that encompasses all DNAs that encode the Zsig13 polypeptide of SEQ ID NO:15. Those skilled in the art will recognize that the degenerate sequence of SEQ ID NO:16 also provides all RNA sequences encoding SEQ ID NO:15 by substituting U for T. Thus, Zsig13 polypeptide-encoding polynucleotides comprising segments of SEQ ID NO:16 and their RNA equivalents are contemplated by the present invention. Table 3 sets forth the one-letter codes used within SEQ ID NO:16 to denote degenerate

nucleotide positions. "Resolutions" are the nucleotides denoted by a code letter. "Complement" indicates the code for the complementary nucleotide(s). For example, the code Y denotes either C or T, and its complement R denotes A or G, A being complementary to T, and G being complementary to C.

TABLE 3

Nucleotide	Resolutions	Complement	Resolutions
A	A	T	T
C	C	G	G
G	G	C	C
T	T	A	A
R	A|G	Y	C|T
Y	C|T	R	A|G
M	A|C	K	G|T
K	G|T	M	A|C
S	C|G	S	C|G
W	A|T	W	A|T
H	A|C|T	D	A|G|T
B	C|G|T	V	A|C|G
V	A|C|G	B	C|G|T
D	A|G|T	H	A|C|T
N	A|C|G|T	N	A|C|G|T

The degenerate codons used in SEQ ID NO:16, encompassing all possible codons for a given amino acid, are set forth in Table 4, below.

TABLE 4

Amino Acid	One-Letter Code	Codons	Degenerate Codon
Cys	C	TGC TGT	TGY
Ser	S	AGC AGT TCA TCC TCG TCT	WSN
Thr	T	ACA ACC ACG ACT	CAN
Pro	P	CCA CCC CCG CCT	CCN
Ala	A	GCA GCC GCG GCT	GCN
Gly	G	GGA GGC GGG GGT	GGN
Asn	N	AAC AAT	AAY
Asp	D	GAC GAT	GAY
Glu	E	GAA GAG	GAR
Gln	Q	CAA CAG	CAR
His	H	CAC CAT	CAY
Arg	R	AGA AGG CGA CGC CGG CGT	MGN
Lys	K	AAA AAG	AAR
Met	M	ATG	ATG
Ile	I	ATA ATC ATT	ATH
Leu	L	CTA CTC CTG CTT TTA TTG	YTN
Val	V	GTA GTC GTG GTT	GTN
Phe	F	TTC TTT	TTY
Tyr	Y	TAC TAT	TAY
Trp	W	TGG	TGG
Ter	.	TAA TAG TGA	TRR
Asn|Asp	B		RAY
Glu|Gln	Z		SAR
Any	X		NNN
Gap	-	---	

One of ordinary skill in the art will appreciate that some ambiguity is introduced in determining a degenerate codon, representative of all possible codons encoding each amino acid. For example, the degenerate codon for serine (WSN) can, in some

circumstances, encode arginine (AGR), and the degenerate codon for arginine (MGN) can, in some circumstances, encode serine (AGY). A similar relationship exists between codons encoding phenylalanine and leucine. Thus, some polynucleotides encompassed by the degenerate sequence may encode variant amino acid sequences, but one of ordinary skill in the art can easily identify such variant sequences by reference to the amino acid sequence of SEQ ID NO:15. Variant sequences can be readily tested for functionality as described herein.

For any Zsig13 polypeptide, including variants and fusion proteins, one of ordinary skill in the art can readily generate a fully degenerate polynucleotide sequence encoding that variant using the information set forth in Tables 3 and 4, above.

Allelic variants and orthologs of the human Zsig13 protein shown in SEQ ID NO:15 can be obtained by conventional cloning methods. The DNA sequence shown in SEQ ID NO:1 or SEQ ID NO:14 or portions thereof can be used as probes or primers to prepare other polynucleotides from cells or libraries (including cDNA and genomic libraries) from humans or other animals of interest, particularly mammals including rodents, rabbits, ungulates, primates, and others of economic importance or biomedical interest. It is preferred to derive probes and primers from regions of the molecule that are relatively conserved within the family of serine proteases, such as residues 141-146, 153-158, 209-214, and 224-229 of SEQ ID NO:2. Methods for isolating additional polynucleotides are known in the art. For example, a cDNA can be cloned using mRNA obtained from a tissue or cell type that expresses the protein. Suitable sources of mRNA can be identified by probing Northern blots with probes designed from the sequences disclosed herein. Preferred sources of mRNA include trachea, small intestine, colon, prostate, and bladder. A library is

then prepared from mRNA of a positive tissue or cell line. A cDNA of interest can then be isolated by a variety of methods, such as by probing with a complete or partial human cDNA or with one or more sets of degenerate probes based on the disclosed sequences. A cDNA can also be cloned using the polymerase chain reaction, or PCR (Mullis, U.S. Patent 4,683,202), using primers designed from the sequences disclosed herein. Of particular interest for cloning are degenerate probes and primers designed from the regions of SEQ ID NO:2 disclosed above and alignment with other serine proteases. Families of preferred degenerate probes are shown in Table 5.

Table 5

Nucleotides (SEQ ID NO:1)	Sense	Complement
582-598	TGY ACN GGN WSN HTN RT (SEQ ID NO:3)	AY NAD NSW NCC NGT RCA (SEQ ID NO:4)
618-634	ACN GCN GSN CAY TGY AT (SEQ ID NO:5)	AT RCA RTG NSC NGC NGT (SEQ ID NO:6)
787-803	WY RTN CCN WVN GGN TGG (SEQ ID NO:7)	CCA NCC NBW NGG NAY RW (SEQ ID NO:8)
831-847	AYN RAY TAY GAY TAY GS (SEQ ID NO:9)	SC RTA RTC RTA RTY NRT (SEQ ID NO:10)

Within an additional method, the cDNA library can be used to transform or transfect host cells, and expression of the cDNA of interest can be detected with an antibody that specifically binds to an epitope of a Zsig13 polypeptide. Similar techniques can also be applied to the isolation of genomic clones.

Within preferred embodiments of the invention the isolated polynucleotides will hybridize to similar sized regions of SEQ ID NO:1 or SEQ ID NO:14, or a sequence complementary to SEQ ID NO:1 or SEQ ID NO:14, under stringent conditions. In general, stringent

conditions are selected to be about 5°C lower than the thermal melting point (T_m) for the specific sequence at a defined ionic strength and pH. The T_m is the temperature (under defined ionic strength and pH) at which 50% of the target sequence hybridizes to a perfectly matched probe. Typical stringent conditions are those in which the salt concentration does not exceed about 0.03 M at pH 7 and the temperature is at least about 60°C, with washes carried out in the presence of EDTA.

The polypeptides of the present invention, including full-length proteins, fragments thereof, and fusion proteins, are produced in genetically engineered host cells according to conventional techniques. Suitable host cells are those cell types that can be transformed or transfected with exogenous DNA and grown in culture, and include bacteria, fungal cells, and cultured higher eukaryotic cells. Techniques for manipulating cloned DNA molecules and introducing exogenous DNA into a variety of host cells are disclosed by Sambrook et al., Molecular Cloning: A Laboratory Manual, 2nd ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 1989.

In general, a DNA sequence encoding a protein of the present invention is operably linked to a transcription promoter and terminator within an expression vector. The vector will commonly contain one or more selectable markers and one or more origins of replication, although those skilled in the art will recognize that within certain systems selectable markers can be provided on separate vectors, and replication of the exogenous DNA can be provided by integration into the host cell genome. Selection of promoters, terminators, selectable markers, vectors and other elements is a matter of routine design within the level of ordinary skill in the art. Many such elements are described in

the literature and are available through commercial suppliers.

To direct Zsig13 polypeptides into the secretory pathway of a host cell, a secretory signal sequence (also known as a leader sequence, prepro sequence or pre sequence) is provided in the expression vector. The secretory signal sequence is joined to a DNA sequence encoding a Zsig13 polypeptide in the correct reading frame. Secretory signal sequences are commonly positioned 5' to the DNA sequence encoding the protein of interest, although certain signal sequences may be positioned 3' to the DNA sequence of interest (see, e.g., Welch et al., U.S. Patent No. 5,037,743; Holland et al., U.S. Patent No. 5,143,830). The secretory signal sequence of Zsig13 (e.g., the human secretory signal sequence of SEQ ID NO:1 from nucleotide 105 to nucleotide 161) is generally preferred for use in mammalian cells. Signals from host cell genes may be preferred in other types of cells (e.g., yeast cells).

Yeast cells, particularly cells of the genus *Saccharomyces*, are suitable for use within the present invention. Methods for transforming yeast cells with exogenous DNA and producing recombinant proteins therefrom are disclosed by, for example, Kawasaki, U.S. Patent No. 4,599,311; Kawasaki et al., U.S. Patent No. 4,931,373; Brake, U.S. Patent No. 4,870,008; Welch et al., U.S. Patent No. 5,037,743; and Murray et al., U.S. Patent No. 4,845,075. A preferred vector system for use in yeast is the *POT*1 vector system disclosed by Kawasaki et al. (U.S. Patent No. 4,931,373), which allows transformed cells to be selected by growth in glucose-containing media. Transformation systems for other yeasts, including *Hansenula polymorpha*, *Schizosaccharomyces pombe*, *Kluyveromyces lactis*, *Kluyveromyces fragilis*, *Ustilago maydis*, *Pichia pastoris*, *Pichia methanolica* and *Candida maltosa* are known in the

art. See, for example, Gleeson et al., J. Gen. Microbiol. 132:3459-3465, 1986; Cregg, U.S. Patent No. 4,882,279; and Hiep et al., Yeast 9:1189-1197, 1993.

The use of *Pichia methanolica* as host for the production of recombinant proteins is disclosed in WIPO Publications WO 97/17450, WO 97/17451, WO 98/02536, and WO 98/02565; and U.S. Patent No. 5,716,808. DNA molecules for use in transforming *P. methanolica* will commonly be prepared as double-stranded, circular plasmids, which are preferably linearized prior to transformation. For polypeptide production in *P. methanolica*, it is preferred that the promoter and terminator in the plasmid be that of a *P. methanolica* gene, such as a *P. methanolica* alcohol utilization gene (*AUG1* or *AUG2*). Other useful promoters include those of the dihydroxyacetone synthase (DHAS), formate dehydrogenase (FMD), and catalase (CAT) genes. To facilitate integration of the DNA into the host chromosome, it is preferred to have the entire expression segment of the plasmid flanked at both ends by host DNA sequences. A preferred selectable marker for use in *Pichia methanolica* is a *P. methanolica ADE2* gene, which encodes phosphoribosyl-5-aminoimidazole carboxylase (AIRC; EC 4.1.1.21), which allows *ade2* host cells to grow in the absence of adenine. For large-scale, industrial processes where it is desirable to minimize the use of methanol, it is preferred to use host cells in which both methanol utilization genes (*AUG1* and *AUG2*) are deleted. For production of secreted proteins, host cells deficient in vacuolar protease genes (*PEP4* and *PRB1*) are preferred. Electroporation is used to facilitate the introduction of a plasmid containing DNA encoding a polypeptide of interest into *P. methanolica* cells. It is preferred to transform *P. methanolica* cells by electroporation using an exponentially decaying, pulsed electric field having a field strength of from 2.5 to 4.5 kV/cm, preferably about

3.75 kV/cm, and a time constant (τ) of from 1 to 40 milliseconds, most preferably about 20 milliseconds.

Other fungal cells are also suitable as host cells. For example, *Aspergillus* cells can be utilized according to the methods of McKnight et al., U.S. Patent No. 4,935,349. Methods for transforming *Acremonium chrysogenum* are disclosed by Sumino et al., U.S. Patent No. 5,162,228.

Cultured mammalian cells can also be used as hosts. Methods for introducing exogenous DNA into mammalian host cells include calcium phosphate-mediated transfection (Wigler et al., Cell 14:725, 1978; Corsaro and Pearson, Somatic Cell Genetics 7:603, 1981: Graham and Van der Eb, Virology 52:456, 1973), electroporation (Neumann et al., EMBO J. 1:841-845, 1982) and DEAE-dextran mediated transfection (Ausubel et al., eds., Current Protocols in Molecular Biology, John Wiley and Sons, Inc., NY, 1987). The production of recombinant proteins in cultured mammalian cells is disclosed by, for example, Levinson et al., U.S. Patent No. 4,713,339; Hagen et al., U.S. Patent No. 4,784,950; Palmiter et al., U.S. Patent No. 4,579,821; and Ringold, U.S. Patent No. 4,656,134. Preferred cultured mammalian cells include the COS-1 (ATCC No. CRL 1650), COS-7 (ATCC No. CRL 1651), BHK (ATCC No. CRL 1632), BHK 570 (ATCC No. CRL 10314) and 293 (ATCC No. CRL 1573; Graham et al., J. Gen. Virol. 36:59-72, 1977) cell lines. Additional suitable cell lines are known in the art and available from public depositories such as the American Type Culture Collection, Rockville, Maryland.

Other higher eukaryotic cells can also be used as hosts, including insect cells, plant cells and avian cells. Transformation of insect cells and production of foreign proteins therein is disclosed by Guarino et al., U.S. Patent No. 5,162,222 and Bang et al., U.S. Patent No. 4,775,624. The use of *Agrobacterium rhizogenes* as a

vector for expressing genes in plant cells has been reviewed by Sinkar et al., J. Biosci. (Bangalore) 11:47-58, 1987.

Prokaryotic host cells for use in carrying out the present invention include strains of the bacteria *Escherichia coli; Bacillus* and other genera are also useful. Techniques for transforming these hosts and expressing foreign DNA sequences cloned therein are well known in the art (see, e.g., Sambrook et al., ibid.). When expressing a Zsig13 protein in bacteria such as *E. coli*, the protein may be retained in the cytoplasm, typically as insoluble granules, or may be directed to the periplasmic space by a bacterial secretion sequence. In the former case, the cells are lysed, and the granules are recovered and denatured using, for example, guanidine isothiocyanate or urea. The denatured protein can then be then refolded and dimerized by diluting the denaturant, such as by dialysis against a solution of urea and a combination of reduced and oxidized glutathione, followed by dialysis against a buffered saline solution. In the latter case, the protein can be recovered from the periplasmic space in a soluble and functional form by disrupting the cells (by, for example, sonication or osmotic shock) to release the contents of the periplasmic space and recovering the protein, thereby obviating the need for denaturation and refolding.

The secretory peptide of Zsig13 (residues -19 through -1 of SEQ ID NO:2) can be used to direct the secretion of other proteins of interest from a host cell. Such use is within the level of ordinary skill in the art. Briefly, a DNA segment encoding the Zsig13 secretory peptide is operably linked to a second DNA segment encoding a protein of interest within a host cell and the cell is cultured according to conventional methods as summarized below. The protein of interest is then recovered from the culture media.

Transformed or transfected host cells are cultured according to conventional procedures in a culture medium containing nutrients and other components required for the growth of the chosen host cells. A variety of suitable media, including defined media and complex media, are known in the art and generally include a carbon source, a nitrogen source, essential amino acids, vitamins and minerals. Media may also contain such components as growth factors or serum, as required. The growth medium will generally select for cells containing the exogenously added DNA by, for example, drug selection or deficiency in an essential nutrient which is complemented by the selectable marker carried on the expression vector or co-transfected into the host cell. *P. methanolica* cells are cultured in a medium comprising adequate sources of carbon, nitrogen and trace nutrients at a temperature of about 25°C to 35°C. Liquid cultures are provided with sufficient aeration by conventional means, such as shaking of small flasks or sparging of fermentors. A preferred culture medium for *P. methanolica* is YEPD.

Recombinant Zsig13 polypeptides (including chimeric polypeptides) can be purified from cells or cell culture media using conventional fractionation and purification methods and media. Ammonium sulfate precipitation and acid or chaotrope extraction may be used for fractionation of samples. Exemplary purification steps include hydroxyapatite, size exclusion, FPLC and reverse-phase high performance liquid chromatography. Suitable anion exchange media include derivatized dextrans, agarose, cellulose, polyacrylamide, specialty silicas, and the like. Exemplary chromatographic media include those media derivatized with phenyl, butyl, or octyl groups, such as Phenyl-Sepharose FF (Pharmacia), Toyopearl butyl 650 (Toso Haas, Montgomeryville, PA), Octyl-Sepharose (Pharmacia) and the

like; or polyacrylic resins, such as Amberchrom CG 71 (Toso Haas) and the like. Suitable solid supports include glass beads, silica-based resins, cellulosic resins, agarose beads, cross-linked agarose beads, polystyrene beads, cross-linked polyacrylamide resins and the like that are insoluble under the conditions in which they are to be used. These supports can be modified with reactive groups that allow attachment of proteins by amino groups, carboxyl groups, sulfhydryl groups, hydroxyl groups and/or carbohydrate moieties. Examples of coupling chemistries include cyanogen bromide activation, N-hydroxysuccinimide activation, epoxide activation, sulfhydryl activation, hydrazide activation, and carboxyl and amino derivatives for carbodiimide coupling chemistries. These and other solid media are well known and widely used in the art, and are available from commercial suppliers. Selection of a particular method is a matter of routine design and is determined in part by the properties of the chosen support. See, for example, Affinity Chromatography: Principles & Methods, Pharmacia LKB Biotechnology, Uppsala, Sweden, 1988. Activated serine proteases are preferably purified by binding to immobilized p-aminobenzamidine (e.g., Benzamidine-Sepharose®; Pharmacia) with subsequent elution using soluble benzamidine (Winkler et al., Bio/Technology 3:990, 1985; Mizuno et al., Biochem. Biophys. Res. Comm. 144:807, 1987).

Proteins comprising affinity tags or other binding domains can be purified by exploiting the properties of the additional domain. For example, immobilized metal ion adsorption chromatography (IMAC) can be used to purify histidine-rich proteins, including proteins comprising poly-histidine tags. Briefly, a gel is first charged with divalent metal ions to form a chelate (Sulkowski, Trends in Biochem. 3:1-7, 1985). Histidine-rich proteins will be adsorbed to this matrix

with differing affinities, depending upon the metal ion used, and will be eluted by competitive elution, lowering the pH, or use of strong chelating agents. Other methods of purification include purification of glycosylated proteins by lectin affinity chromatography and ion exchange chromatography ("Guide to Protein Purification", Methods Enzymol., Vol. 182, M. Deutscher, (ed.), Academic Press, San Diego, 1990, pp.529-39).

Zsig13 polypeptides can also be prepared through chemical synthesis. The polypeptides may be glycosylated or non-glycosylated; pegylated or non-pegylated; and may or may not include an initial methionine amino acid residue.

When proteins are produced intracellularly (such as in prokaryotic host cells) or by *in vitro* synthesis, protein refolding (and optionally reoxidation) procedures as generally disclosed above are advantageously used.

It is preferred to purify Zsig13 proteins to >80% purity, more preferably to >90% purity, even more preferably >95%, and particularly preferred is a pharmaceutically pure state, that is greater than 99.9% pure with respect to contaminating macromolecules, particularly other proteins and nucleic acids, and free of infectious and pyrogenic agents. Preferably, a purified protein is substantially free of other proteins, particularly other proteins of animal origin.

Proteins of the present invention can be used within laboratory and industrial settings to cleave proteins for a variety of purposes that will be evident to those skilled in the art. The proteins can be used alone to provide specific proteolysis or can be combined with other proteases to provide a "cocktail" with a broad spectrum of activity. Representative laboratory uses include the removal of proteins from biological samples, such as preparations of nucleic acids; and for digesting

proteins in conjunction with peptide mapping and sequencing. Within industry, the proteins of the present invention can be formulated in laundry detergents to aid in the removal of protein stains, and can be used within the large scale preparation of recombinant proteins to specifically cleave fusion proteins, including removing affinity tags. The proteins of the present invention can be added to a variety of compositions and solutions as proteolytically active enzymes or as protease precursors. In the latter arrangement, the protein is subsequently activated, such as by the addition of an activating protease.

The proteins of the present invention are also useful as research reagents to identify novel protease inhibitors. Briefly, test samples (compounds, broths, extracts, and the like) are added to protease assays as disclosed above to determine their ability to inhibit substrate cleavage. Inhibitors identified in this way can be used in industry and research to reduce or prevent undesired proteolysis. As with proteases, inhibitors can be combined to increase the spectrum of activity.

Zsig13 proteins and protein fragments can also be used to prepare antibodies that specifically bind to zsig13 proteins. As used herein, the term "antibodies" includes polyclonal antibodies, monoclonal antibodies, antigen-binding fragments thereof such as $F(ab')_2$ and Fab fragments, single chain antibodies, and the like, including genetically engineered antibodies. Non-human antibodies can be humanized by grafting non-human CDRs onto human framework and constant regions, or by incorporating the entire non-human variable domains (optionally "cloaking" them with a human-like surface by replacement of exposed residues, wherein the result is a "veneered" antibody). In some instances, humanized antibodies may retain non-human residues within the human variable region framework domains to enhance proper

binding characteristics. Through humanizing antibodies, biological half-life can be increased, and the potential for adverse immune reactions upon administration to humans is reduced. One skilled in the art can generate humanized antibodies with specific and different constant domains (i.e., different Ig subclasses) to facilitate or inhibit various immune functions associated with particular antibody constant domains. Alternative techniques for generating or selecting antibodies useful herein include *in vitro* exposure of lymphocytes to Zsig13 protein, and selection of antibody display libraries in phage or similar vectors (for instance, through use of immobilized or labeled Zsig13 protein). Antibodies are defined to be specifically binding if they bind to a Zsig13 protein with an affinity at least 10-fold greater than the binding affinity to control (non-Zsig13) protein. The affinity of a monoclonal antibody can be readily determined by one of ordinary skill in the art (see, for example, Scatchard, Ann. NY Acad. Sci. 51: 660-672, 1949).

Methods for preparing polyclonal and monoclonal antibodies are well known in the art (see for example, Hurrell, J. G. R., Ed., Monoclonal Hybridoma Antibodies: Techniques and Applications, CRC Press, Inc., Boca Raton, FL, 1982). As would be evident to one of ordinary skill in the art, polyclonal antibodies can be generated from a variety of warm-blooded animals such as horses, cows, goats, sheep, dogs, chickens, rabbits, mice, and rats. The immunogenicity of a Zsig13 polypeptide can be increased through the use of an adjuvant such as alum (aluminum hydroxide) or Freund's complete or incomplete adjuvant. Polypeptides useful for immunization also include fusion polypeptides, such as fusions of a Zsig13 protein or a portion thereof with an immunoglobulin polypeptide or with maltose binding protein. The polypeptide immunogen may be a full-length molecule or a

portion thereof. If the polypeptide portion is "hapten-like", such portion may be advantageously joined or linked to a macromolecular carrier (such as keyhole limpet hemocyanin (KLH), bovine serum albumin (BSA) or tetanus toxoid) for immunization.

A variety of assays known to those skilled in the art can be utilized to detect antibodies which specifically bind to Zsig13 proteins. Exemplary assays are described in detail in Antibodies: A Laboratory Manual, Harlow and Lane (Eds.), Cold Spring Harbor Laboratory Press, 1988. Representative examples of such assays include: concurrent immunoelectrophoresis, radio-immunoassays, radio-immunoprecipitations, enzyme-linked immunosorbent assays (ELISA), dot blot assays, Western blot assays, inhibition or competition assays, and sandwich assays.

Antibodies to Zsig13 proteins can be used for affinity purification of the protein, within diagnostic assays for determining circulating levels of the protein; for detecting or quantitating soluble Zsig13 protein or protein fragments as a marker of underlying pathology or disease; for immunolocalization within whole animals or tissue sections, including immunodiagnostic applications; for immunohistochemistry; and as antagonists to block protein activity *in vitro* and *in vivo*. Antibodies to Zsig13 can also be used for tagging cells that express Zsig13; for affinity purification of Zsig13 proteins; in analytical methods employing FACS; for screening expression libraries; and for generating anti-idiotypic antibodies. For certain applications, including *in vitro* and *in vivo* diagnostic uses, it is advantageous to employ labeled antibodies. Suitable direct tags or labels include radionuclides, enzymes, substrates, cofactors, inhibitors, fluorescent markers, chemiluminescent markers, magnetic particles and the like; indirect tags or labels may feature use of biotin-avidin or other

complement/anti-complement pairs as intermediates. Antibodies of the present invention can also be directly or indirectly conjugated to drugs, toxins, radionuclides and the like, and these conjugates used for *in vivo* diagnostic or therapeutic applications.

While not wishing to be bound by theory, tissue distribution of Zsig13 mRNA suggests that the protein may play a defensive role. Proteases that serve anitbiotic or antitoxin functions are known (Gabay, ibid.; Scocchi et al., ibid.). Proteins of the present invention may thus be useful as antibiotics and/or antitoxins. They may further be used as diagnostic indicators of infection by assaying body fluids for the presence of Zsig13. Zsig13 proteins or fragments thereof can be detected using, for example, immunoassay techniques employing antibodies specific for Zsig13 epitopes. Assays can be performed using soluble or immobilized antibodies in a variety of known formats.

A Zsig13 gene, a probe comprising Zsig13 DNA or RNA, or a subsequence thereof can be used to determine if the Zsig13 gene is present on chromosome 11 or if a mutation has occurred. Detectable chromosomal aberrations at the Zsig13 gene locus include, but are not limited to, aneuploidy, gene copy number changes, insertions, deletions, restriction site changes and rearrangements. These aberrations can occur within the coding sequence, within introns, or within flanking sequences, including upstream promoter and regulatory regions, and may be manifested as physical alterations within a coding sequence or changes in gene expression level. Analytical probes will generally be at least 20 nucleotides in length, although somewhat shorter probes (14-17 nucleotides) can be used. PCR primers are at least 5 nucleotides in length, preferably 15 or more nt, more preferably 20-30 nt. Short polynucleotides can be used when a small region of the gene is targetted for

analysis. For gross analysis of genes, a polynucleotide probe may comprise an entire exon or more. Probes will generally comprise a polynucleotide linked to a signal-generating moiety such as a radionucleotide. In general, gene-based diagnostic methods comprise the steps of (a) obtaining a genetic sample from a patient; (b) incubating the genetic sample with a polynucleotide probe or primer as disclosed above, under conditions wherein the polynucleotide will hybridize to complementary polynucleotide sequence, to produce a first reaction product; and (iii) comparing the first reaction product to a control reaction product. A difference between the first reaction product and the control reaction product is indicative of a genetic abnormality in the patient. Genetic samples for use within the present invention include genomic DNA, cDNA, and RNA. The polynucleotide probe or primer can be RNA or DNA, and will comprise a portion of SEQ ID NO:1 or SEQ ID NO:14, the complement of SEQ ID NO:1 or SEQ ID NO:14, or an RNA equivalent thereof. Suitable assay methods in this regard include molecular genetic techniques known to those in the art, such as restriction fragment length polymorphism (RFLP) analysis, short tandem repeat (STR) analysis employing PCR techniques, ligation chain reaction (Barany, *PCR Methods and Applications* 1:5-16, 1991), ribonuclease protection assays, and other genetic linkage analysis techniques known in the art (Sambrook et al., *ibid.*; Ausubel et. al., *ibid.*; A.J. Marian, *Chest* 108:255-65, 1995). Ribonuclease protection assays (see, e.g., Ausubel et al., *ibid.*, ch. 4) comprise the hybridization of an RNA probe to a patient RNA sample, after which the reaction product (RNA-RNA hybrid) is exposed to RNase. Hybridized regions of the RNA are protected from digestion. Within PCR assays, a patient genetic sample is incubated with a pair of polynucleotide primers, and the region between the primers is amplified and

recovered. Changes in size or amount of recovered product are indicative of mutations in the patient. Another PCR-based technique that can be employed is single strand conformational polymorphism (SSCP) analysis (Hayashi, *PCR Methods and Applications* 1:34-38, 1991).

Radiation hybrid mapping is a somatic cell genetic technique developed for constructing high-resolution, contiguous maps of mammalian chromosomes (Cox et al., Science 250:245-250, 1990). Partial or full knowledge of a gene's sequence allows one to design PCR primers suitable for use with chromosomal radiation hybrid mapping panels. Commercially available radiation hybrid mapping panels that cover the entire human genome, such as the Stanford G3 RH Panel and the GeneBridge 4 RH Panel (Research Genetics, Inc., Huntsville, AL), are available. These panels enable rapid, PCR-based chromosomal localizations and ordering of genes, sequence-tagged sites (STSs), and other nonpolymorphic and polymorphic markers within a region of interest. This technique allows one to establish directly proportional physical distances between newly discovered genes of interest and previously mapped markers. The precise knowledge of a gene's position can be useful for a number of purposes, including: 1) determining relationships between short sequences and obtaining additional surrounding genetic sequences in various forms, such as YACs, BACs or cDNA clones; 2) providing a possible candidate gene for an inheritable disease which shows linkage to the same chromosomal region; and 3) cross-referencing model organisms, such as mouse, which may aid in determining what function a particular gene might have.

The invention is further illustrated by the following, non-limiting examples.

Example 1

Tissue distribution of Zsig13 mRNA was analyzed using Human Multiple Tissue Northern Blots (obtained from Clontech, Inc., Palo Alto, CA). A 40-bp DNA probe (ZC 11,667; SEQ ID NO:11) was radioactively labeled with ^{32}P using T4 polynucleotide kinase and forward reaction buffer (GIBCO BRL, Gaithersburg, MD) according to the supplier's specifications. The probe was purified using a push column (Nuctrap™ column; Stratagene Cloning Systems, La Jolla, CA). Prehybridization and hybridization were carried out in a commercially available solution (ExpressHyb™ hybridization solution; Clontech Laboratories, Inc., Palo Alto, CA). Blots were hybridized overnight at 42°C, washed in 2X SSC, 0.05% SDS at room temperature, then in 1X SSC, 0.1% SDS at 60°C. Two transcripts were observed: a strongly hybridizing ~1.8 kb band and a fainter band at approximately 4.0 kb.

An RNA Master Dot Blot (Clontech Laboratories) that contained RNAs from various tissues that were normalized to eight housekeeping genes was also probed with the 40-bp oligonucleotide probe (SEQ ID NO:11). The blot was prehybridized, then hybridized overnight with 10^6 cpm/ml of probe of 42°C according to the manufacturer's specifications. The blot was washed with 2X SSC, 0.05% SDS at room temperature, then in 1X SSC, 0.1% SDS at 60°C. After a four-day exposure, signals were seen in trachea, aorta, bladder, and fetal kidney.

Example 2

Zsig13 was mapped to chromosome 11 using the commercially available GeneBridge 4 Radiation Hybrid Panel (Research Genetics, Inc., Huntsville, AL). The GeneBridge 4 Radiation Hybrid Panel contains PCRable DNAs from each of 93 radiation hybrid clones, plus two control DNAs (the HFL donor and the A23 recipient). A publicly available WWW server (http://www-genome.wi.mit.edu/cgi-

bin/contig/rhmapper.pl) allows mapping relative to the Whitehead Institute/MIT Center for Genome Research (WICGR) radiation hybrid map of the human genome, which was constructed with the GeneBridge 4 Radiation Hybrid Panel.

For the mapping of Zsig13, 20 μl reaction mixtures were set up in a PCRable 96-well microtiter plate (Stratagene Cloning Systems, La Jolla, CA) and incubated in a thermal cycler (RoboCycler™ Gradient 96; Stratagene Cloning Systems). Each of the 95 PCR reactions consisted of 2 μl 10X KlenTaq PCR reaction buffer (Clontech Laboratories, Inc.), 1.6 μl dNTPs mix (2.5 mM each, Perkin-Elmer, Foster City, CA), 1 μl sense primer (ZC 13,508; SEQ ID NO:12), 1 μl antisense primer (ZC 13,509; SEQ ID NO:13), 2 μl of a commercially available density increasing agent and tracking dye (RediLoad; Research Genetics, Inc., Huntsville, AL), 0.4 μl of polymerase/antibody mixture (50X Advantage™ KlenTaq Polymerase Mix; Clontech Laboratories, Inc.), 25 ng of DNA from an individual hybrid clone or control and ddH_2O for a total volume of 20 μl. The reaction mixtures were overlaid with an equal amount of mineral oil and sealed. The PCR cycler conditions were as follows: an initial 5 minute denaturation at 95°C; 35 cycles of a 1 minute denaturation at 95°C, 1 minute annealing at 62°C and 1.5 minute extension at 72°C; followed by a final extension of 7 minutes at 72°C. The reaction products were separated by electrophoresis on a 3% NuSieve® GTG agarose gel (FMC Bioproducts, Rockland, ME).

The results showed that Zsig13 maps 417.10 cR_3000 distal from the top of the human chromosome 11 linkage group on the WICGR radiation hybrid map. Proximal and distal framework markers were D11S1979 and D11S2384, respectively. The use of surrounding markers positions Zsig13 in the 11q22.1 region on the integrated LDB chromosome 11 map (The Genetic Location Database,

University of Southhampton, WWW server: http://cedar.genetics. soton.ac.uk/public_html/). This region of chromosome 11 is fairly rich in proteases.

From the foregoing, it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.